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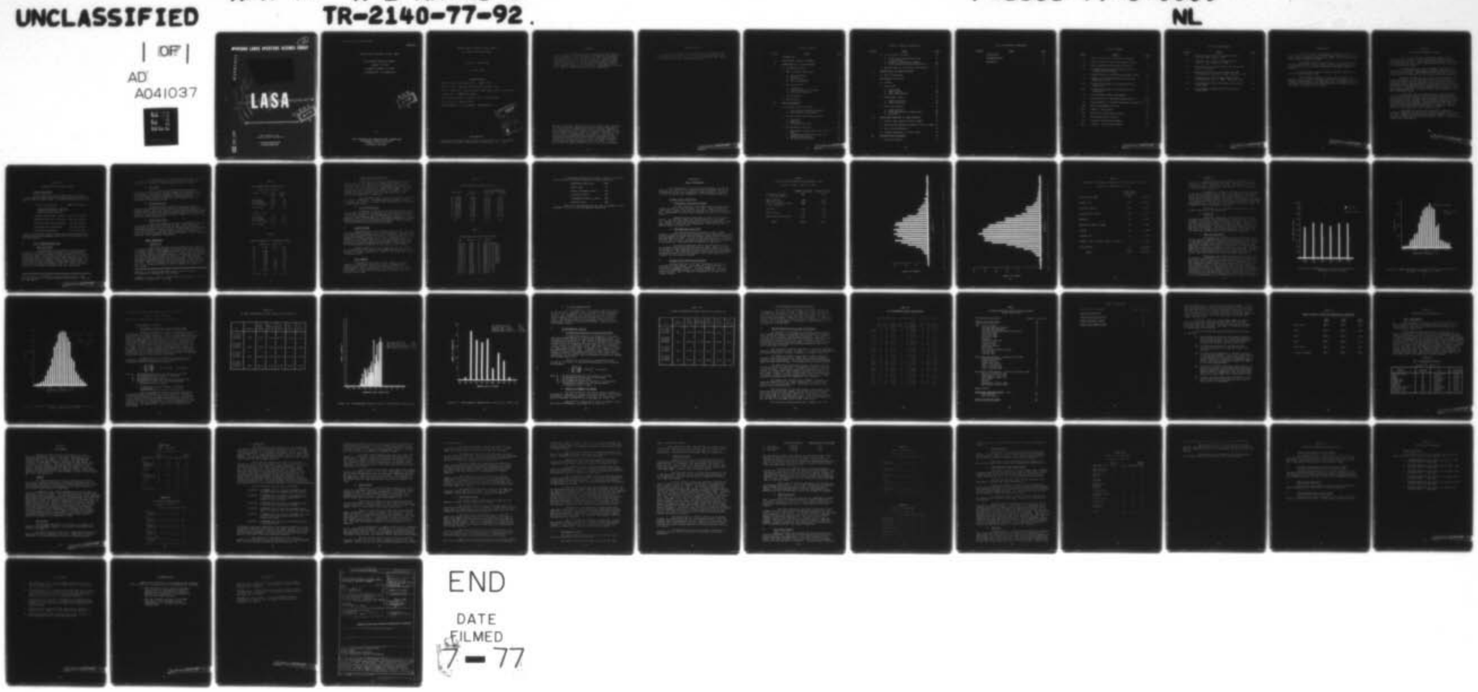

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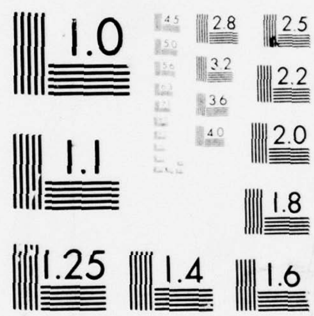

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MONTANA LARGE APERTURE SEISMIC ARRAY

LASA

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FORD AEROSPACE AND
COMMUNICATIONS CORPORATION

214 NORTH 30TH STREET
BILLINGS, MONTANA

Technical Report 2140-77-92 ✓

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MONTANA LARGE APERTURE SEISMIC ARRAY

SEMI-ANNUAL TECHNICAL REPORT

PROJECT VT 7708

CONTRACT F08606-77-C-0009 New

1 OCTOBER 1976 - 31 MARCH 1977

by

FORD AEROSPACE AND COMMUNICATIONS CORPORATION
ENGINEERING SERVICES DIVISION
214 North 30th Street
Billings, Montana

MONTANA LARGE APERTURE SEISMIC ARRAY

SEMI-ANNUAL TECHNICAL REPORT

Report No. 2140-77-92

26 April 1977

IDENTIFICATION

AFTAC Project Authorization No.: VELA T/7708

Title of Work: Montana Large Aperture Seismic Array

Name of Contractor: Ford Aerospace and Communications Corporation

Contract No.: F08606-77-C-0009

Time period covered: 1 October 1976 - 31 March 1977

Date of Issue: 26 April 1977

Program Manager: R. E. Matkins (406)245-6332

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ABSTRACT

The continued operation, maintenance, and array improvement activities at the Montana LASA during the period between October 1, 1976, and March 31, 1977, are described. Array operations are detailed. Progress in seismic event processing is reported. Seismograph measurements, IBM 360 computer reliability and maintainability statistics, and PDP-7 computer programs are presented. Maintenance activities at the data and maintenance centers are discussed.

ACKNOWLEDGEMENT

Ford Aerospace and Communications Corporation wishes to recognize the excellent technical direction provided to the Montana LASA project during this contract period by Capt. Robert J. Woodward at the VELA Seismological Center.

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INTRODUCTION

This is the first semi-annual technical report of the activity by Ford Aerospace & Communications Corporation on the Montana Large Aperture Seismic Array (LASA), Project VELA T/7708, under contract F08606-77-C-0009.

The primary goal of this project is to operate and maintain the LASA in a manner which produces unique high quality seismic data for use by other government sponsored research projects.

The work described here began 1 October 1976 and continued through 31 March 1977.

The sections following in this report describe the operation of the various systems installed at the LASA, the performance measurements on the equipment, the teleseismic and near-regional event reporting, the PDP-7 computer programming, and the maintenance performed on the systems.

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SECTION I

SEMI-ANNUAL SUMMARY OF EVENTS

This, first Semi-annual Technical Summary report, describes the activities at the Montana LASA during October 1976 through March 1977. These activities include the operation and maintenance of the systems installed both in the array and at the data center (LDC).

The LASA Processing System (LASAPS) operated continuously with the Seismic Data Analysis Center (SDAC) 92.1% of this six month period. System/360 failures and their correction accounted for the majority of the on-line interruptions (83.7%).

Digital recording of the array data by the PDP-7 computer continued on a full-time basis with the exception of an average 66 minute per day interruption for off-line program processing and system maintenance. The digital recordings were available from the LDC during the 60-day retention cycle before their reuse. Recordings of event periods since November 1, 1975, are still available at the LDC on edited tapes produced by the PDP-7 AUTO-EDIT system.

Teleseismic event processing using film recordings and on-line computer playouts were routinely performed with the average daily result of 16.8 events or phases reported to VSC. Also, periodic near regional and strip-mine blast listings added an average of 7.1 events/day. Comparisons with USGS show our reported magnitudes slightly higher (0.07 units ave) than the PDE's, our locations differing by about 5.3 degrees, and the 90% detection threshold of our reports at 4.99.

Equipment and facilities maintenance allowed the continued operation of the array in a manner similar to previous periods. Mechanical components with their inherent wear with age caused added concern to the maintenance effort in implementing repairs and replacements.

SECTION II

OPERATION OF ALL LASA SYSTEMS

A. LASAPS OPERATIONS

The LDC computer provided LASA data to the SDAC transcontinental data link 92.1% of the six-month period from October 1976 thru March 1977. Interruptions have occurred due to:

corrective maintenance	288.1 hrs (6.60%)
active maintenance, 112.2 hr awaiting personnel, 119.1 hr awaiting parts, 56.8 hr	
computer halts/power failures	15.3 hrs (0.35%)
administrative uses (training)	12.7 hrs (0.29%)
other LDC systems inoperative	9.8 hrs (0.22%)
4.8 Kbaud line inoperative	9.7 hrs (0.22%)
preventive maintenance	8.5 hrs (0.19%)

Sinewave test signals replaced the three LP and the SP north-south horizontal seismometer signals from site D2 during this reporting period.

B. PDP-7 COMPUTER OPERATIONS

1. Data Recording

The LASA Inner Array Recording System (LIARS) operated on an almost full-time basis to record LASA data. Recordings covering an average of 22.9 hr/day for the 182-day period were made. This system previously described by Potter (1975) provides four modes of array data recording either 10 or 20 samples/sec (s/s) from either a 10 or 16 SP sensor configuration of all 13 subarrays. 6288 LIARS tape recordings were produced using the slow-mode (10 s/s), short (10 sensor) format; no recordings were made using the other modes.

Potter, George. "LASA Inner Array Recording System" LASA Program Description. Ford Aerospace & Communications. Billings Mt 26 MAR 75.

Interruptions in the data recording were necessary to support other LDC operations and logistics functions for 161.3 hr (3.7%) and for computer downtime 36.5 hr (0.8%)

2. Auto-Edit

The recording of edited event data continued throughout this reporting period allowing the preparation of 16 new master-edit tapes containing 1727 event periods. These LDC recordings, described by Matkins (1976), provide an efficient means of data playout for event analysis and for event data retention at the LDC.

3. Event Detection

Automatic event detection continued using the same event detection processor routine as used and reported by Needham (1969). The event detection lists speed the manual analog film reading process from which we prepare our daily teleseismic reports. Event detections also provide a means of verifying the SP array sensing performance.

4. Event Processing

Event processing at the LDC is performed to assist in our teleseismic event reporting to VSC. Event data with amplitudes too small to pick from the analog film recordings are processed digitally through a filter, a beam former, and a cross-correlation routine. The time picks from either these strip charts or film recordings are further processed to obtain location and other event parameter information.

C. ARRAY OPERATIONS

1. Monitoring

The array and data center systems are monitored on a continuous basis to provide an up-to-date site/sensor status information input to the LASAPS processor and to alert maintenance to trouble sources. Interruptions of the array data are shown in the monthly operations summary reports. SP data was interrupted 214.3 hr during this period; LP, 157.9 hr. Each SP subarray averaged 2.7 hr/month outage; LP, 2.9 hr/month. These averages represent improvements over the previous report of 23% (SP) and 45% (LP). Table I indicates the data interruptions by the purpose of the outage and Table II shows a summary by subarray of the outages.

Matkins, R. E. Montana LASA Semi-annual technical report. T/R 2126-76-75 (AD-A023 263) 23 JAN 1976.

Needham, R. and A. Steele. Montana LASA data analysis techniques. S-110-33 Billings, MT May 1969.

TABLE I

DATA INTERRUPTIONS BY PURPOSE OF OUTAGE

OCTOBER 1976 - MARCH 1977

SP ARRAY, 13 SITES	TOTAL HOURS OUT	AVERAGE PER SITE
LDC TESTING	19.78	1.52
SITE FAILURES	17.38	1.34
LMC MAINTENANCE	28.73	2.21
TELCO TEST/OUTAGE	148.43	11.42
TOTAL SP ARRAY	214.32	16.49
LP ARRAY, 9 SITES		
LDC TESTING	19.53	2.17
SITE FAILURES	1.33	0.15
LMC MAINTENANCE	16.56	1.84
TELCO TEST/OUTAGE	120.46	13.38
TOTAL LP ARRAY	157.88	17.54

TABLE II

SUMMARY OF SUBARRAY DATA INTERRUPTION OUTAGES

OCTOBER 1976 - MARCH 1977

SITE	SP DATA	LP DATA	TELCO
A0	8.96	9.14	41.54
B1	18.79	-	6.31
B2	2.38	-	7.86
B3	1.65	-	6.40
B4	4.42	-	6.75
C1	3.70	2.17	7.12
C2	2.92	3.25	9.65
C3	4.49	4.45	8.11
C4	4.93	5.20	6.40
D1	2.59	2.30	18.67
D2	1.87	2.52	8.17
D3	5.64	6.02	9.58
D4	3.55	2.37	11.22
TOTAL HRS	65.89	37.45	147.78

2. Communications Monitoring

Monitoring of the array communications circuits between each of the thirteen subarrays and the data center indicated about the same level of performance as previously observed. The long term circuit availability (since DEC 1970) of array circuits again did not change from 0.99687. Circuit outages-those which normally exceed 2 or 3 minutes-of each subarray are shown together with the short-and long-term circuit availabilities in Table III.

The extended outages exceeding a two-hour duration are listed in Table IV. No communications equipment failures are shown; all incidents resulted from either weather conditions or man-caused events.

3. Array Calibrations

Sinusoidal calibrations are performed daily using Program TESP for the SP seismographs to determine the condition of the array equipment. LP seismographs are routinely tested each week using Program TELP for sinusoidal calibrations, Program FREEK for free period measurement,and Program MASPOS for measuring and positioning the LP seismometer masses. Other computer controlled tests are periodically performed.

D. ANALOG SYSTEM

Throughout most of this reporting period the two LASA SP Develocorders operated on-line with the array. By using two units and alternating them daily one is always in operation even during film changes and one is ready for recording in case of a malfunction in the operating unit. The recording format consisted of center holes from the C-and D-Ring and AO subarrays plus the attenuated signals from AO and D4. Develocorder film recordings dating from 24 DEC 73 are stored in the library.

Analog signals from three subarrays (D1, D3, and D4) are transmitted to the National Earthquake Information Service facility in Golden, Colorado, as a part of their on-line seismic recording system.

E. DATA LIBRARY

Recording of the arrays seismic data by the PDP-7 computer's seven-track tape units using our LIARS format covered 4171.1 hours or 95.5% of the six-month period. These 6288 magnetic tape recordings were recycled through the LDC's Data Library so that each recording was retained for at least 60 days before reuse.

TABLE III

ARRAY COMMUNICATIONS OUTAGE STATISTICS

SITE-CIRCUIT		OUTAGE 10/76-03/77	CIRCUIT AVAILABILITIES SHORT TERM 10/76-03/77	LONG TERM 12/70-03/77
A0	4GD2704	40.250	99.078	99.474
B1	4GD2701	22.350	99.488	99.807
B2	4GD2710	7.967	99.818	99.710
B3	4GD2705	6.533	99.850	99.818
B4	4GD2707	7.800	99.812	99.731
C1	4GD2708	7.117	99.837	99.844
C2	4GD2709	10.334	99.763	99.674
C3	4GD2711	12.366	99.717	99.385
C4	4GD2706	6.400	99.853	99.742
D1	4GD2714	18.634	99.573	99.654
D2	4GD2715	4.884	99.888	99.843
D3	4GD2712	13.400	99.693	99.489
D4	4GD2713	12.650	99.710	99.706
TOTALS		170.685	99.699	99.687

TABLE IV

EXTENDED ARRAY DATA COMMUNICATIONS OUTAGES

DATE	DURATION	SITE	REASON
10/17/76	03:50	D3	STORM IN ARRAY
12/02/76	02:01	A0	CABLE CUT AT ANGELA
12/02/76	02:01	B1	CABLE CUT AT ANGELA
12/02/76	03:01	B2	CABLE CUT AT ANGELA
12/02/76	02:26	B3	CABLE CUT AT ANGELA
12/02/76	02:47	B4	CABLE CUT AT ANGELA
12/02/76	02:47	C1	CABLE CUT AT ANGELA
12/02/76	03:06	C2	CABLE CUT AT ANGELA
12/02/76	03:18	C3	CABLE CUT AT ANGELA
12/02/76	02:26	C4	CABLE CUT AT ANGELA
12/02/76	03:57	D1	CABLE CUT AT ANGELA
12/02/76	03:27	D3	CABLE CUT AT ANGELA
12/02/76	03:53	D4	CABLE CUT AT ANGELA
01/03/77	03:55	A0	FROST ON LINE
02/06/77	29:28	A0	FROST ON LINE
02/06/77	04:00	D4	FROST ON LINE
02/06/77	04:00	D1	FROST ON LINE
02/07/77	06:05	D1	FROST ON LINE
02/18/77	02:30	C3	UNKNOWN

The LASA Data Library now contains 3152 of the 2400-ft tapes which are currently divided into these categories:

LIARS Recording Cycle	2161
Master Edit	61
Events (permanent files)	401
Calibration Data	165
Programming (quality tapes)	128
Administrative	236

There are 4 disc packs with the LPS 75 (LASAPS) system available for use in the 360 computer operations.

SECTION III

ARRAY PERFORMANCE

The performance of the array as determined locally is based on the results of our seismic event processing, SP and LP seismometer testing and reliability studies. Results from each of these activities and summarized in the following paragraphs.

A. Seismic Event Processing

1. Teleseismic Processing Summary

We have reported to VSC 1468 events and 236 phases between October 1, 1976 and March 31, 1977. These events are classified in Table V and show an average of 16.8 detections per day. Approximate locations were indicated for 31% of the detected events.

Magnitudes were determined for 867 of the located events. The smallest magnitude reported was 3.6; the largest 7.2. Figure 3.1 shows the distribution of these magnitudes. The distribution of all 3756 event magnitudes reported since July 1, 1975 is shown in Figure 3.2.

2. Near-Regional Detections

The LASA near-regional detection reports which indicate a portion of the near-regional activity and identify interferring signals continued with 25 reports issued between October 1, 1976 and March 31, 1977. A total of 235 near-regional or regional arrivals were covered. Unidentified events account for the majority of the arrivals. Locations were estimated for 29 events.

Periodic supplements report the blasting activity at the known strip mines located near the LASA. Table VI shows the number of blasts detected from each of the several strip mines in the region. The blasting activity during this six-month period increased by about 17% to an average of 6.8 blasts/day from 5.8 reported for the previous period.

B. Seismic Event Processing Analysis

Limited analysis of the LDC teleseismic reporting is performed as time permits. Four areas of study which are currently in progress include: (1) confirmation of reported events with USGS/NEIS lists; (2) location capability; (3) magnitude accuracy; and (4) detection threshold of the LDC teleseismic reports.

TABLE V

CLASSIFICATION OF DETECTED TELESEISMIC EVENTS

October 1, 1976 - March 31, 1977

	Number of Events	Daily Average
Located teleseisms (excluding PKP's)	867	4.76
PKP (located)	26	0.14
PKP (unlocated)	176	0.97
Poor or weak teleseisms (not located)	399	2.19
pP Phases	149	0.82
Other Phases	87	0.48
Unprocessed detections	1349	7.41
TOTAL	3053	16.77

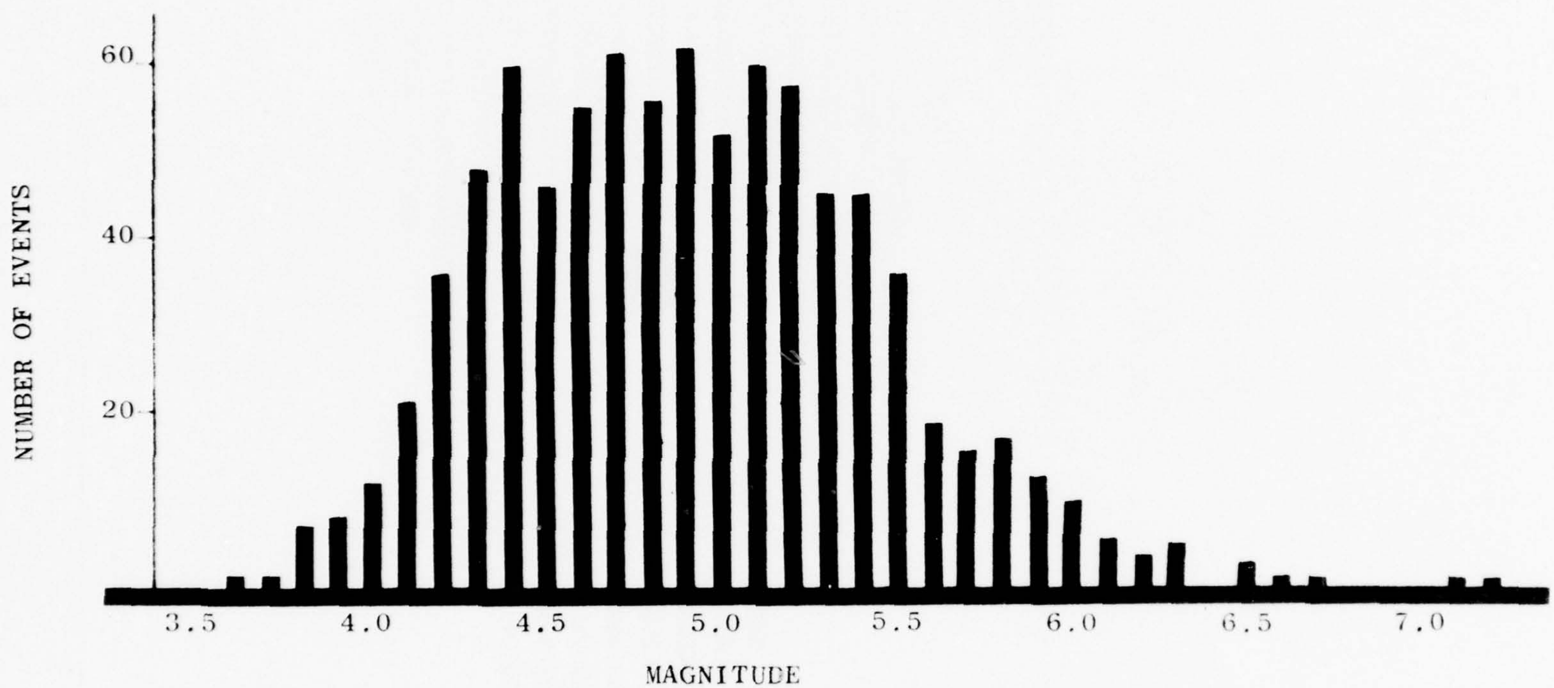


Figure 3.1 Magnitude Distribution of Located Events, October 1976-March 1977

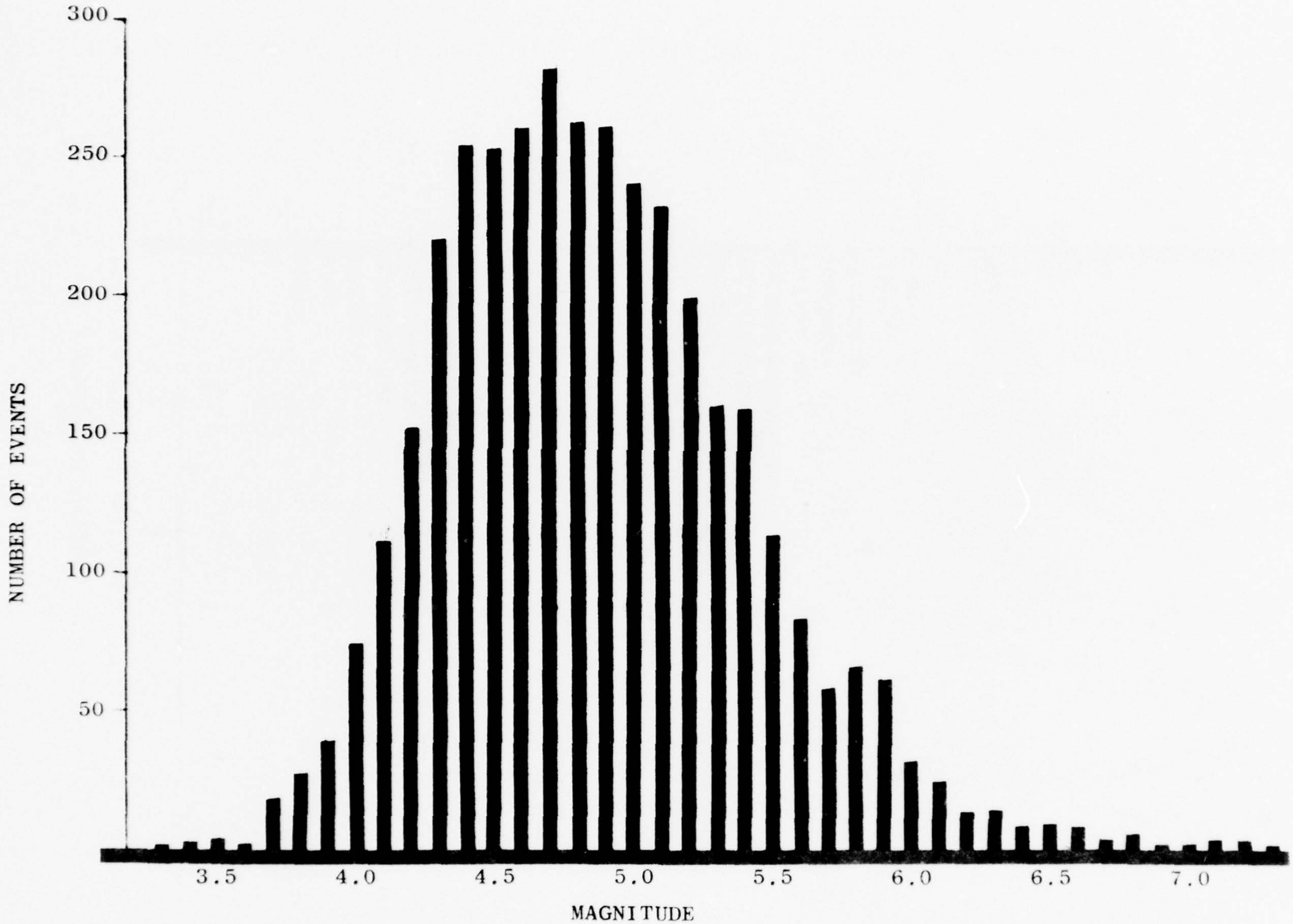


Figure 3.2 Magnitude Distribution of Located Events, July 1, 1975-March 31, 1977

TABLE VI

Summary of Strip-mine Blasting Activities Reported by LDC

October 1, 1976-March 31, 1977

	Number Blasts Reported	
Colstrip, MT (WE)	550	(44.4%)
Decker, MT	230	(18.5%)
Colstrip, MT (P)	124	(10.0%)
Sarpy Creek, MT (W)	100	(8.1%)
Wyoming	80	(6.5%)
British Columbia, Canada	67	(5.4%)
Unknown	50	(4.0%)
Unknown, NE	31	(2.5%)
Seismic Crew in Array, Series of Shots	7	(0.5%)
South Dakota	1	(0.1%)
TOTAL	1240	(100.0%)

1. Location

Event locations are estimated for those events with good signal arrivals at the LASA. About 60% of the 1468 teleseismic events reported during this six-month period included locations. The monthly distribution of this percentage is indicated in Figure 3.3.

A comparison between event locations as determined at the LDC and those given by USGS in the PDE's was made using events which occurred between June 17 and September 30, 1975. Using the events which showed good signal correlation across the array (Type 1 classification), location error averaged 4.57 degrees (σ, 3.78 degrees) for the 135 events within 80 degrees of LAO and 5.33 degrees (σ, 4.10 degrees) for the 204 events within PKP boundary of about 105 degrees from LAO.

Investigation of location accuracy for specific seismic regions is in progress now.

2. Magnitude

Magnitude comparisons are made between the LDC calculations and the event magnitudes as they are later listed in PDEs. The results, which are shown in Figure 3.4 for the past six months and in Figure 3.5 from July 1975, indicate the LDC estimates differed by only 0.14 and 0.07 units for the two periods, respectively. The quality of these results led us to make only one change in our local procedures, viz., adjusting the magnitude estimate when a depth phase was available.

3. Detection Threshold

We compared the events reported by the LDC teleseismic reports (October 1976 thru March 1977) with those listed in the PDEs to measure the quality of this daily report. Since the PDE lists many events either with no magnitude or with a magnitude estimated from only a few stations, we used the PDE magnitude of 4.6 as a threshold. Above 4.6, our report contained 62.2% of the PDE events; below 4.6, we reported 16.2%. Of the 660 events with a magnitude of 4.6 or greater which we did not report, 549 (83.2%) were more than 90 degrees from LAO.

Following a more fromal procedure we estimate the m_b detection threshold of our daily reports at 4.99 (90%) and 4.56 (50%) based on 3756 event magnitudes reported during the $21\frac{1}{2}$ consecutive months between June 16, 1975 and March 31, 1977. The measurement method used a least squares fitted straight line through a part of the cumulative log frequency-magnitude distribution between 7.3 and 4.7 magnitude limits, a reasonably straight portion of the distribution. The 90% and 50% detection thresholds are those magnitudes at which the actual number of events falls 10% and 50%, respectively, below the level predicted by the extrapolation of the straight-line, frequency-magnitude

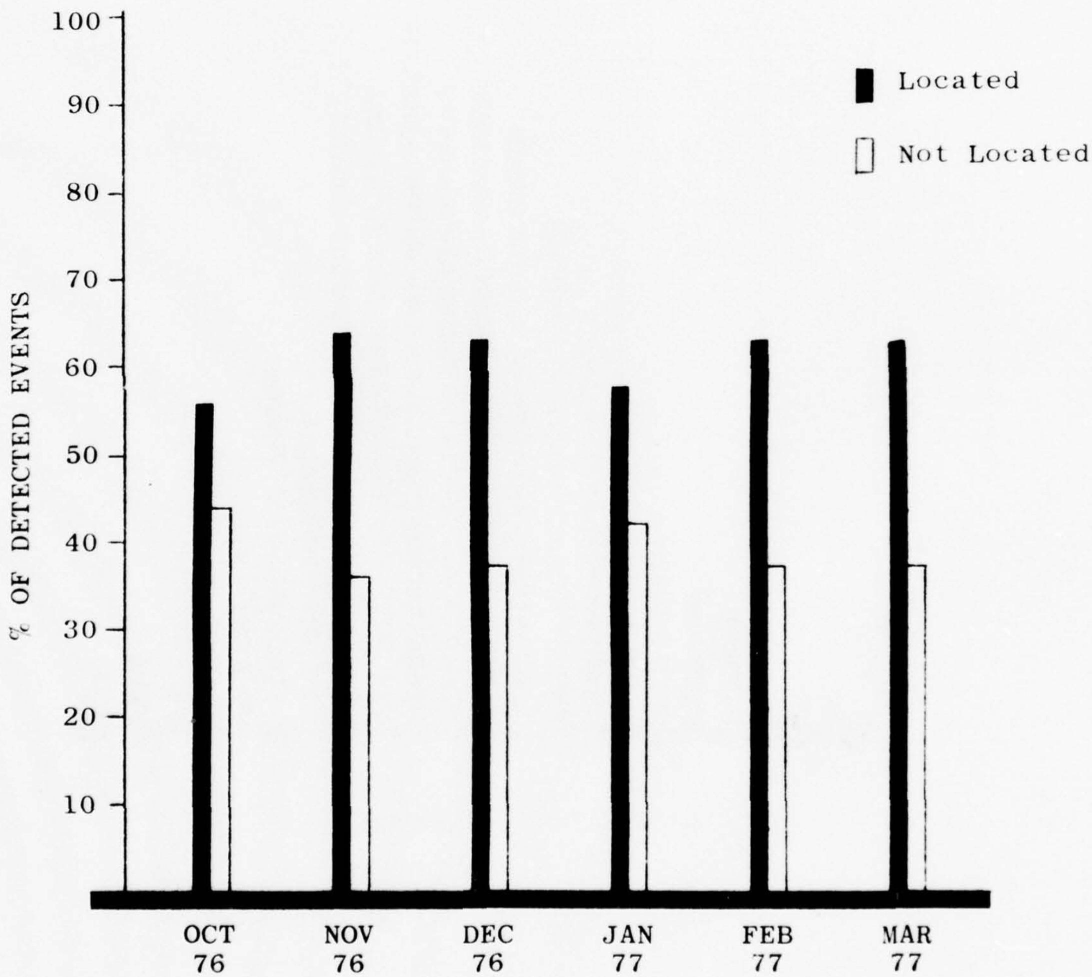


Figure 3.3 Distribution of Located and Non-located Teleseismic Events by Month

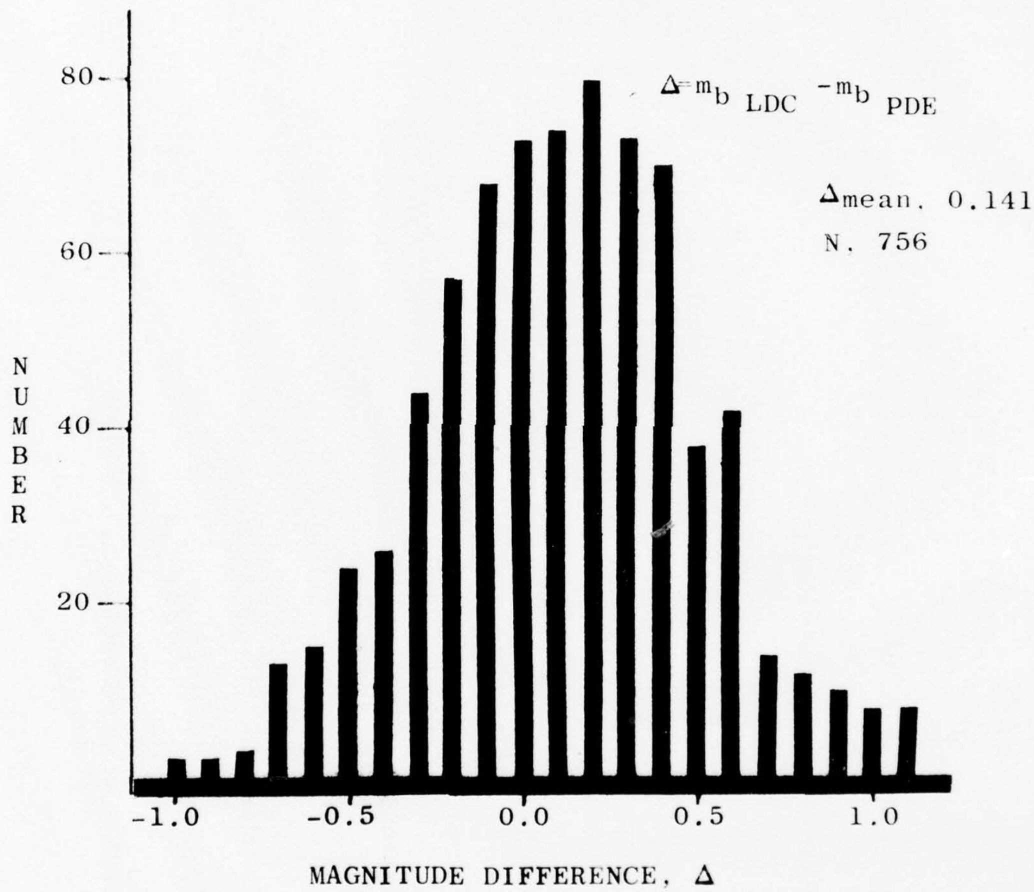


Figure 3.4 Magnitude Difference between LASA and PDE Calculations October 1, 1976-March 31, 1977

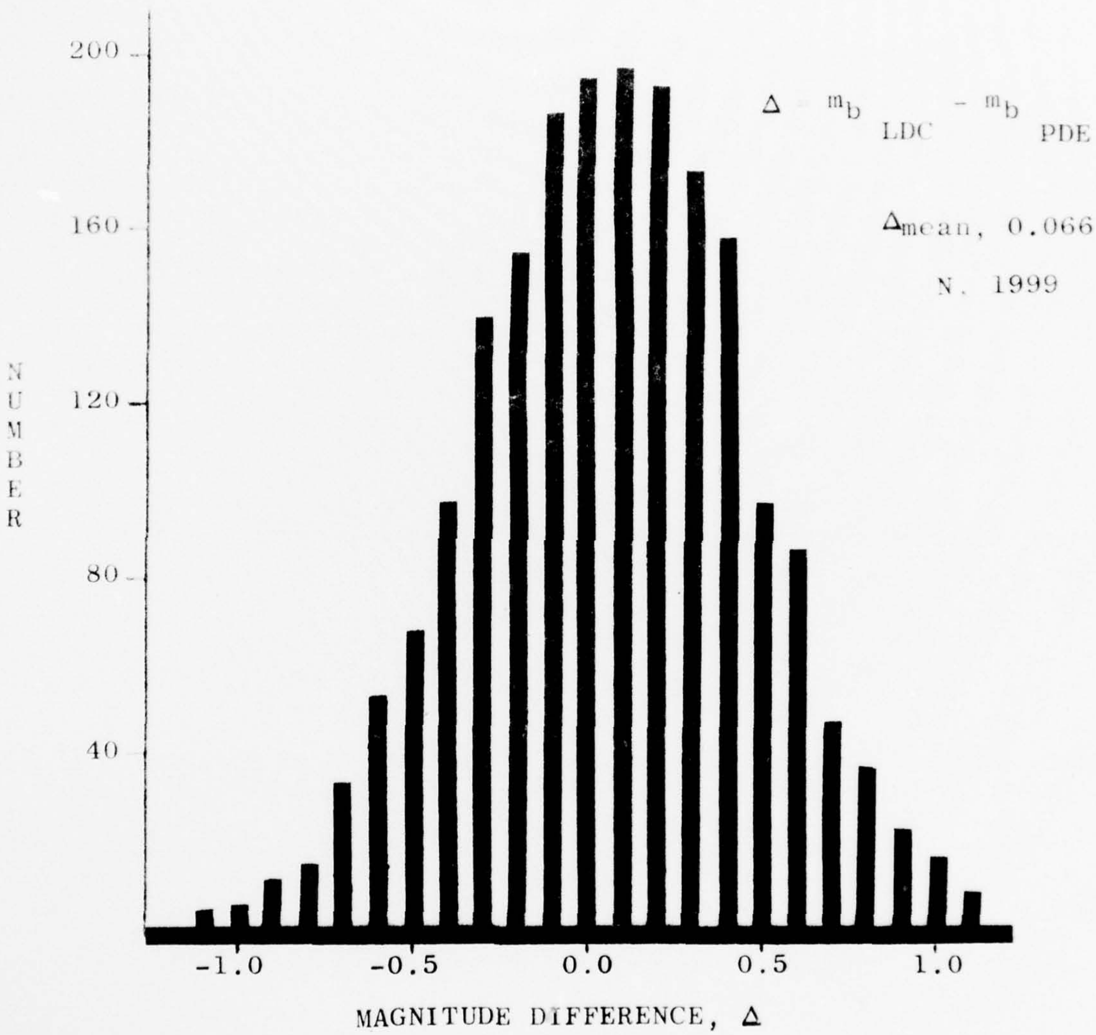


Figure 3.5 Magnitude Difference Between LASA and PDE Calculations
July 1, 1975-March 31, 1977

distribution towards lower magnitudes. The equation,

$$\log N = 8.86 - 1.13\ m_b$$

defines the straight line used with this data set.

C. SP Seismometer Testing

1. Performance Measurement Using Program TESP

Weekly measurement of each of the LASA short period seismographs is provided remotely by PDP-7 program TESP, which measures the seismograph response to a one-second sinusoidal signal. During the past 6 months the average mean sensitivity of the 210 LASA SP seismographs was 19.91 mV/nm at one-second periods with the average standard deviation being 0.63 mV/nm. The tolerance limits for the SP seismograph sensitivity have been set at 20 ±3 mV/nm. The past three contract averages along with the first six months of the current contract are summarized in Table VII. The number of functioning sensors, sensitivity mean, sensitivity standard deviation, maximum sensitivity for the array, minimum sensitivity for the array, and the difference between the maximum and minimum sensitivity are given by contract.

Sensitivity is a function of the output of the seismometer divided by the input to the seismometer and is calculated using the following relationship:

$$S = \left(\frac{4\pi^2 M}{G_c\ T^2}\right)\frac{E_o}{I} = 1.01 \times 10^3\ \frac{E_o}{I} \quad \text{volts/meter}$$

where S = SP Channel Sensitivity at period T in seconds
M = SP Seismometer moving mass in kilograms
E_o = SP Channel Output in volts
G_c = SP Seismometer generator constant in newtons/amp
I = Calibration current into the SP seismometer Calibration Coil in amps.

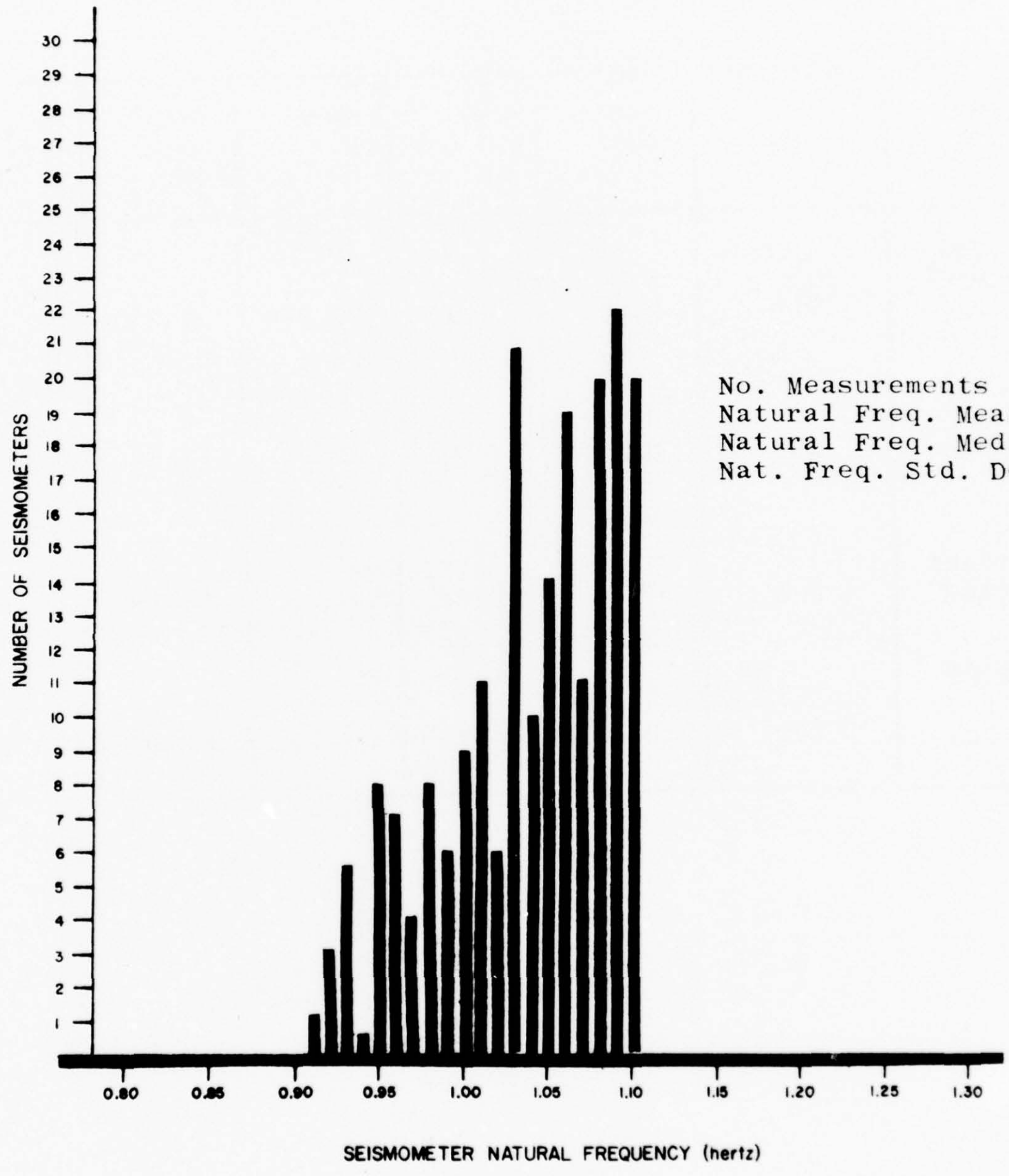
2. Seismometer Natural Frequency & Damping Measurements

The SP seismometer natural frequency and damping field measurements completed this period have only slightly revised the distributions of these two parameters. Histograms of the natural frequency and damping measurements are shown in Figures 3.6 and 3.7, respectively. The two sensors with a damping ratio of .643 were surface (10 ft. deep) installations at subarray D1. The measurements, made during a windy day, are questionable.

TABLE VII

SP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

SP	Sensors	Sens Mean mV/nm	Sens Std Dev mV/nm	Sens Max. mV/nm	Sens Min. mV/nm	Sens Dev. mV/nm
VT 7708 Contract Average	208	19.91	0.63	22.45	17.24	5.21
VT 6708 Contract Average	206	19.83	0.83	22.91	16.69	6.22
VT 4708 Contract Average	206	20.05	0.85	23.36	16.78	6.58
VT 2708 Contract Average	208	20.14	0.79	22.86	16.96	5.90



No. Measurements	209
Natural Freq. Mean	1.036
Natural Freq. Median	1.05
Nat. Freq. Std. Dev.	0.051

Figure 3.6 SP Seismometer Natural Frequency Distribution, March 1977

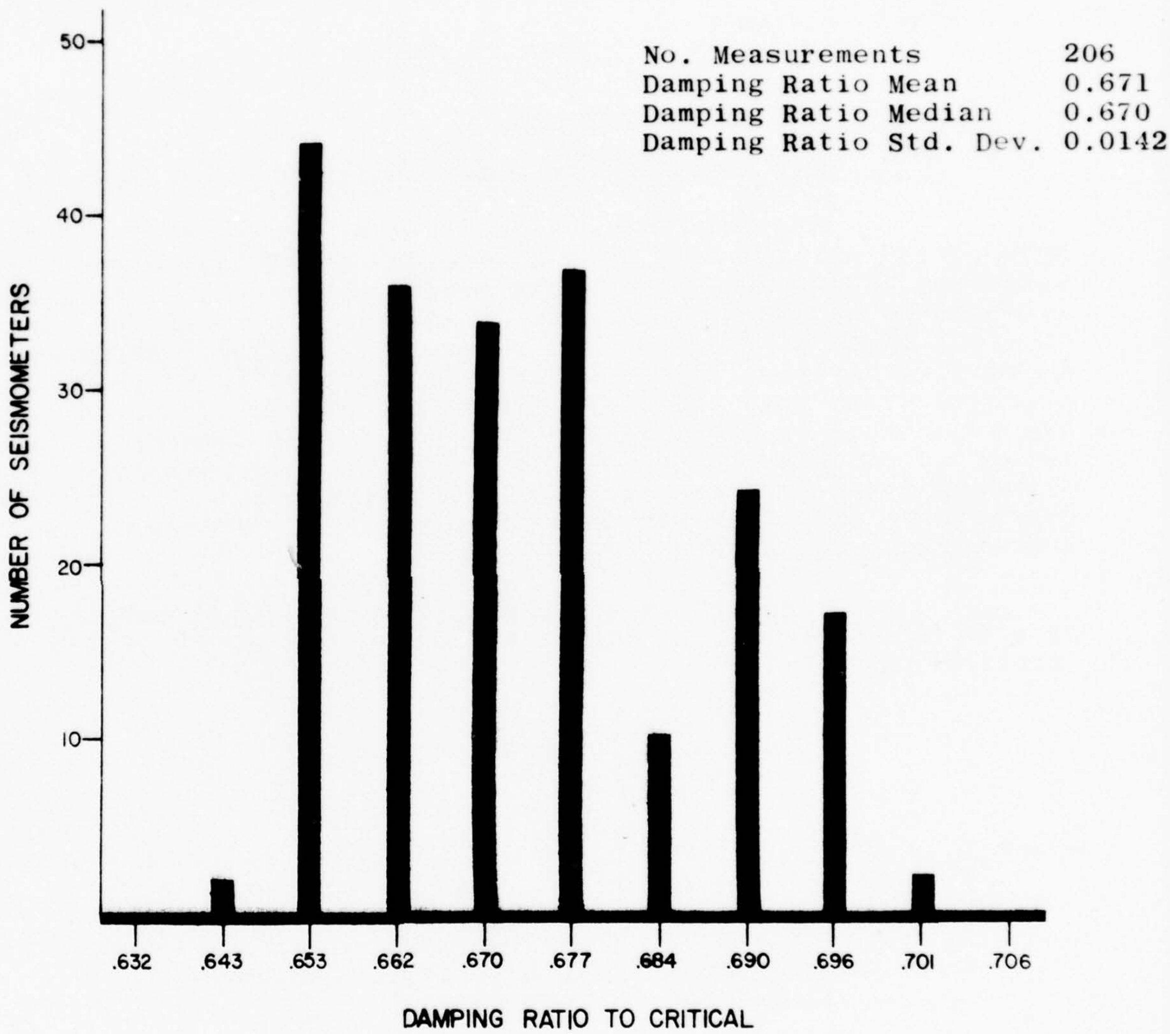


Figure 3.7 SP Seismometer Damping Ratio Distribution, March 1977

3. SP Sensor Replacements

A brief analysis of the replacements and repairs of the SP sensor equipment shows 20 different WHV maintenance actions: one seismometer, 16 amplifiers and three wellhead vaults. One seismometer was replaced because of low output. Three wellhead vaults were dried out and sealed to correct leaks. The 16 RA-5 amplifier replacements corrected seven inoperative channels, six distorted outputs, and three erratic and unstable outputs.

D. LP Seismometer Testing

1. Performance Measurement Using Program TELP

Program TELP measures the response of the LASA long period seismographs to a 25-second sinusoidal signal. The tolerance limits for the 27 long period seismographs have been established at 350 ± 50mV/μm. The first six months of the current contract shows an average mean sensitivity of 350.4 mV/μm which is well within the tolerance limits. The past three contract averages along with the first six months of the current contract are summarized in Table VIII. Included in the summary are the number of functioning sensors, sensitivity mean, sensitivity standard deviation, maximum sensitivity for the array, minimum sensitivity for the array, and the difference between the maximum and minimum sensitivity.

Sensitivity, a function of seismograph output divided by the input, is calculated according to the following relationship:

$$S = \left(\frac{4\pi^2 M}{G_C \ T^2}\right)\frac{E}{I} = 22.56 \ \frac{E_o}{I} \quad \text{volts/meter}$$

where S = LP Channel Sensitivity at period T in seconds
M = LP Seismometer moving mass in kilograms
E_o = LP Channel output in volts
G_C = LP Seismometer generator constant in newtons/amp
I = Calibration current into the LP Seismometer Calibration Coil in amps

2. Results of MASPOS and FREECK

The free period of the array's 24 LP seismometers averaged 20.1 seconds (σ, 0.10s) over the 25 weeks of this reporting period. Remote adjustments to maintain the free period to a 20.0 ± 1.0 seconds totalled 37 for an average of 1.4 per test.

Mass position centering to within ± 1.40mm required 191 remote adjustments, an average of 7.3 per test.

TABLE VIII

LP ARRAY PERFORMANCE TESTING SENSITIVITY STATISTICS

LP	No. Sensors	Sens Mean mV/μm	Sens Std Dev mV/μm	Sens Max. mV/μm	Sens Min. mV/μm	Sens Dev. mV/μm
VT 7708 Contract Average	24	350.4	20.5	393.09	306.5	86.6
VT 6708 Contract Average	25	339.9	19.2	383.9	294.9	89.0
VT 4708 Contract Average	26	337.4	18.2	376.7	297.9	78.8
VT 2708 Contract Average	22	347.0	16.0	382.6	319.0	63.6

3. LP Seismometer Positioning Analysis

The long term positioning statistics for the LP seismometers are shown in Table IX where the remote adjustments for both mass positioning (since 6 DEC 71) and free period correction (since 2 JAN 73) are shown and total 1938. The mean-time-between-adjustment (MTBA) for each seismometer is shown and varies from 11.36 days for sensor D4 N/S to 64.80 days for sensor D3 E/W. The average MTBA for the array is 1.06 days and for a seismometer is 28.52 days.

E. IBM 360 Computer Operational Performance

An increase in the number of extended outages of the LDC's LASAPS processor, an IBM 360 Model 44 computer, warranted a review of the computers operating performance. Five system failures have occurred since December 1975 which resulted in outage periods of more than 50 hours. This computer has been operating at the LDC since April 1968. For the purpose of this review failure classifications and maintainability statistics since July 1973 are used.

The incident of failure according to equipment category has been classified and shown in Table X. As shown the 1052 Printer/Keyboard had the most frequent incidence of failure, 36 or 51%

The 2044-G Processing Units CPU or A-gate produced the most circuit board failures (IBM's SLT cards) requiring 14 separate card replacements. The failures were well distributed among the main CPU sections; no section had more than 2 failures.

The 1052 Printer/Keyboard failures resulted from the mechanical nature of this unit. Adjustments corrected over 75% of the failures. Replacement parts were required for the items subject to normal wear; most frequent item was the rotate control tape. Usage as a factor influencing failure was shown when the number of 1052 incidents dropped during the period of SDAC program development when the LASAPS was not operating.

The Single Disc Storage Device (SDSD) is another unit whose mechanical nature has been responsible for some recent failures, six since January 1975. Failures in the other peripheral units have been rare.

The reliability of the 360 system is indicated by the mean-time-between-failure (MTBF) for the 66 failures which have occurred during the 1368 days (32,832 hr) since July 1, 1973. The system MTBF is 20.7 days (497.5 hr). When the 1052 failures are subtracted the system MTBF increases to 44.8 days (1074.4 hr) For the CPU only the MTBF is 69.0 days (1656.0 hr).

The mean-time-between-maintenance (MTBM) since July

TABLE IX

LP SEISMOMETER REMOTE ADJUSTMENTS

	MASS POSITION ADJUSTS			FREE PERIOD ADJUSTS			COMBINED ADJUSTMENTS		
	10/76 TO 04/77	12/71 TO 04/77	AVG DAYS-BETWEEN ADJUSTS	10/76 TO 04/77	01/73 TO 04/77	AVG DAYS-BETWEEN ADJUSTS	10/76 TO 04/77	LONG TERM	AVG DAYS-BETWEEN ADJUSTS
	5	44	44.27	3	13	119.31	8	57	30.69
4d NS	4	34	57.29	0	16	96.94	4	50	34.99
A0 EW	5	58	33.59	1	8	193.88	6	66	26.51
C1 V	7	47	41.45	2	15	103.40	9	62	28.22
C1 NS	6	42	46.38	2	19	81.63	8	61	28.68
C1 EW	4	45	43.29	1	12	129.25	5	57	30.69
C2 V	6	54	36.07	3	15	103.40	9	69	25.36
C2 NS	9	64	30.44	6	38	40.82	15	102	17.15
C2 EW	14	92	21.17	1	14	110.79	15	106	16.50
C3 V	8	71	27.44	0	3	517.00	8	74	23.64
C3 NS	8	73	26.68	1	10	155.10	9	83	21.08
C3 EW	11	82	23.76	1	9	172.33	12	91	19.23
C4 V	6	54	36.07	0	4	387.75	6	59	29.65
C4 NS	3	25	77.92	1	5	310.20	4	30	58.32
C4 EW	3	57	34.18	0	2	775.50	3	59	29.65
D1 V	5	43	45.30	1	8	193.88	6	51	34.30
D1 NS	24	124	15.71	1	19	81.63	25	143	12.23
D1 EW	3	95	20.51	0	12	129.25	3	107	16.35
D2 V	7	57	34.18	0	7	221.57	7	64	27.34
D2 NS	4	50	38.96	0	2	775.50	4	50	34.99
D2 EW	6	78	24.97	0	2	775.50	6	78	22.43
D3 V	10	76	25.63	0	5	310.20	10	81	21.60
D3 NS	6	31	62.84	4	8	193.88	10	39	44.86
D3 EW	6	20	97.40	4	7	221.57	10	27	64.80
D4 V	7	57	34.18	1	4	387.75	8	61	28.68
D4 NS	11	127	15.34	4	27	57.44	15	154	11.36
D4 EW	3	47	41.45	0	10	155.10	3	57	30.69

TABLE X

CLASSIFICATION OF IBM 360 SYSTEM FAILURES
(SINCE JULY 1973)

360/44 System Equipment	Number of Failures
2044-G Processing Unit	**20**
CPU: Cycle Control	0
Storage Address Register	2
Storage Data Register	1
Operations Register/Comm Chan Control	1
Controls Clock	2
Data Flow (B2)	1
Data Flow (B3)	0
Display	0
Interrupt Controls	1
Controls (C2)	0
Controls (C3)	0
Operation Decode	2
Interrupts	0
Gen. Purpose Register Stack	2
Console (E1)	0
Console (E2)	2
High Speed Multiplexer: Subchannel A1 (SCA)	1
Subchannel B1(SCB)	0
Common Control	0
Common Data Flow	0
Chan 1 IF Control	0
Chan 1 Control SCA	0
Chan 1 Control SCB	0
Multiplexer/1052 Adapter: Priority Interrupt (A2)	1
Priority Interrupt (A3)	0
1052 Adapter Logic (B1)	0
1052 Adapter Logic (C1)	1
Data Flow	0
Funnels	0
Multiplexer Control (B3)	0
Multiplexer Control (C3)	0
Memory Stack	1
Single Disc Storage Device: Disc	**6**
Disc Control	0
Disc IF Control	0
1052-7 Printer/Keyboard	**36**

TABLE X (CONTINUED)

360/44 System Equipment	Number of Failures
2501-B1 Card Reader	0
1827-1 Data Control Unit	1
1826 Data Adapter Unit	2
2701-1 Data Adapter Unit	0

1973 is 204.22 hours. The mean-time-to-repair (MTTR) or active corrective-maintenance time has been 6.32 hours. When the mean time awaiting parts (1.57 hr) and personnel (8.08 hr) are added, the mean time to correct failures has been 15.98 hours. Preventive maintenance has averaged 1.65 hours for the 82 instances covered by this study. The total maintenance downtime (MDT) equals 1443.95 hours.

To detect trends the yearly MTBF, MTBM, and MTTR statistics have been listed with those for the 3 3/4-year period on Table XI. The 1977 figures do not compare favorably with the other years; however, the short, 3-month period may be influencing the statistics.

After reviewing the data associated with the study, we conclude:

(1) The significant failures which might indicate aging of the system, viz., those SLT cards within the 2044 processor, do not show sufficient evidence for greater concern at this time.

(2) No particular section of the CPU has been affected by failure to a greater extent than another.

(3) The 1052 Printer-Keyboard is the main location of 360 system failures. Its failure rate depends upon usage and results mostly from mechanical failures which are corrected by component adjustments. Periodic overhaul can reduce the number of failures significantly.

(4) The time to diagnose and repair CPU failures has become less as the on-site maintenance crew has gained "hands-on" experience with the 360 system. Limited built-in diagnostics and increased IBM maintenance costs make this a significant factor.

(5) Finally, the 95% operational availability goal for the 360 system still appears valid when an annual basis is considered.

TABLE XI

TREND ANALYSIS OF IBM 360 MAINTENANCE PARAMETERS

	MTBF (hr)	MTBM (hr)	MTTR (hr)
1973 (1/2)	546.0	182.5	3.60
1974	673.8	236.8	6.86
1975	438.0	159.3	6.34
1976	625.7	282.6	6.76
1977 (1/4)	196.4	154.3	7.07
To last incident	496.7	204.2	6.32

SECTION IV

IMPROVEMENTS AND MODIFICATIONS

A. PDP-7 PROGRAMMING

The development and maintenance of programs for the PDP-7 computer continue to provide an important part of the overall task of operating and improving the Montana Array as a seismological observatory.

The programs completed during the first half of Project VT/7708 are listed in Table XII. Programming activity supported LDC operations (1) by converting two existing programs to operate during array on-line data recording, e.g. LIARS version 1 (VL1) of the magnetic tape duplicate and verify program (DUP/VER), (2) by updating the computer usage program to agree with current computer uses, (3) with improvements to paper tape read in program, and (4) by updating the SP array sensor polarity check program to run in less time. Two programs were prepared to assist local seismic analysis work, viz., GRAPH and DIAZ (event distance and azimuth from site LAO). Our logistics effort was helped by new government property and table list programs and the addition of error detection to the material inventory program.

TABLE XII

PDP-7 PROGRAMMING ACTIVITY

October 76 - March 77

PROGRAM	VERSION	BY	APPROVED
Property List	V1	Lidderdale	10/76
DIAZ	V2	Potter	11/76
POLCK	V2	Maxwell	12/76
TABLE LIST	V3	Lidderdale	12/76
PUNCH HRI	V2	Maxwell	01/77
GRAPH	V1	Potter	01/77
DUP/VER	VL1	Potter	02/77
Material Inventory	VL2	Lidderdale	03/77
Computer Use	V2	Maxwell	03/77
Computer Use	VL1	Maxwell	03/77

SECTION V

MAINTENANCE

LASA maintenance activity is divided into three different categories: Data Center (LDC), Maintenance Center (LMC) and Facilities Support. The LDC in Billings operates and maintains the following five systems: The IBM 360/44 computer, the DEC PDP-7 computer, LDC Digital, LDC Analog, and the LDC Test and Support. The LMC located in Miles City maintains all array equipment systems which are comprised of SP Sensor, LP Sensor, Meteorological, SEM, and Power. Facilities Support provides maintenance of buildings, vehicles, land leases, and array facilities such as cable trenches, access trails, fences, WHV sites, and CTH sites.

A. Summary

The main maintenance activities during this 6-month period were subarray inspections, preventive maintenance at both LMC and LDC, IBM 360 system repairs, checking and servicing of all environmental equipment in LDC computer room, cable repairs in array, and several projects in LDC shop.

A summary of the total maintenance activity is given in Table XIII where the number of work order actions in the LMC, LDC, and utility areas are shown. The 439 completed work orders represent 565 separate and traceable actions by the maintenance activities and since several repair actions may result from the clearing of one particular trouble, the number of maintenance actions can exceed the number of work orders. The work orders do not indicate the man-hours involved but are indicative of the work load. The system work orders completed consisted of 249 preventive maintenance routines, 148 corrective maintenance, 2 modifications, and 19 utility actions. A total of 22 items of equipment were repaired in the LMC and LDC shops. The backlog in the shop of 49 items primarily consisted of printed circuit cards at LDC and RA-5 amplifiers and HS-10-1A seismometers at LMC.

B. Data Center

Five systems maintained at the LDC are the IBM-360/44 Computer, the DEC PDP-7 Computer, the Digital, the Analog, and the Test and Support.

A total of 221 work orders were completed for 332 maintenance actions plus 4 repairs in the shop. Table XIV provides a breakdown of the LDC maintenance actions by system and month.

TABLE XIII

SUMMARY - WORK ORDERS

OCTOBER 1976 - MARCH 1977

WORK ORDER TYPE	BACKLOG START OF PERIOD	INITIATED	COMPLETED	BACKLOG END OF PERIOD
LMC				
SYSTEM -A	0	183	182	1
SUBASSEMBLY-B	6	31	9	28
COMPONENT -C	2	7	8	1
TOTALS	8	221	199	30
LDC				
SYSTEM -A	9	218	217	10
SUBASSEMBLY-B	3	0	2	1
COMPONENT -C	17	3	2	18
TOTALS	29	221	221	29
UTILITY	1	35	19	17
COMBINED TOTALS	38	477	439	76

TABLE XIV

DATA CENTER MAINTENANCE ACTIONS

OCTOBER 1976 - MARCH 1977

	OCT	NOV	DEC	JAN	FEB	MAR	TOTALS
360							
CORRECTIVE	0	2	3	4	3	2	14
PREVENTIVE	3	3	2	1	0	0	9
PDP-7							
CORRECTIVE	1	7	8	5	9	8	38
PREVENTIVE	20	30	21	25	22	29	147
DIGITAL							
CORRECTIVE	0	0	0	0	0	0	0
PREVENTIVE	9	8	5	4	4	5	35
ANALOG							
CORRECTIVE	2	3	5	2	1	3	16
PREVENTIVE	7	6	0	0	0	1	14
TEST AND SUPPORT							
CORRECTIVE	5	5	2	6	6	8	32
PREVENTIVE	4	2	7	1	5	8	27
TOTALS	51	66	53	48	50	64	332

1. System 360

The maintenance responsibility for the IBM 360/44 is handled locally with assistance from IBM as needed. The LDC 360 system consists of (1) a 2044-G Processing Unit, (2) a 1052-7 Printer/Keyboard, (3) a 2501-B1 Card Reader, (4) an 1827-1 Data Control Unit (5) an 1826 Data Adapter Unit, and (6) a 2701-1 Data Adapter. During this period there were 14 repairs on the system and 9 preventive maintenance actions.

There were 16 instances of failure on the 360 system with two of the work orders still open at the end of this 6-month period waiting further maintenance and parts. There were six problems in the CPU caused by failure of SLT cards. The other failures were: four problems with the disk drive, three with the 1052 printer/keyboard, and three failures with the 2501 card reader. October was the only month during this period that the system operated without any failures. In addition the "Invalid OP Decode" problem (previously reported) still exists in the CPU. The problem was bypassed by installing a modified 5803350 card in location 1AC4E4. Trouble shooting of this problem will be on a non-interrupt basis of the system operation.

The six CPU card failures were as follows:

11-02-76: A 5801881 card in location 01A-B1F2 caused all SDR data to be tagged with bad parity.

11-23-76: A 5800143 card in location 01A-A4D2 caused a continuous 1/0 request stopping the machine in an 1/0 cycle.

01-01-77: A 5803308 card in location 01A-B2D6 caused a loss of bits 16-23 from the GPR's.

01-18-77: A 5801881 card in location 01A-D4E6 caused GPR 6 to read all the time from the GPR array.

01-19-77: A 5803311 card in location 01A-E2B3 prevented the CPU from being operated manually in Single Cycle mode.

02-02-77: A 5806146 card in location 01A-A2K4 blocked 1C and SAR bit 16.

A different type card failed in all six failures and all occurred on different boards in the system. All power supplies were within ripple and level tolerances and cooling ducts and fans were clean and functioning properly. No conclusions can be made from these failures that would indicate preventive measures.

Two failures of the disk drive were caused by broken connecting wires on the moving portion of the head assembly. This is not an unusual failure and can be expected. An

intermittant homing problem did not re-occur after cleaning the head assembly and position pot but probably was related to the subsequent wire problems. A failure to read data was corrected by head alignment. A complete head alignment could not be done as we do not have a CE disk with alignment tracks.

The 1052 caused problems twice when the space bar jammed on the keyboard. Parts were ordered that should stop this problem. Another problem occured when gold particles from the C5/C6 gold plated contacts accumulated on a phenolic spacer and allowed a signal to be developed across the normally open contacts. The end result was a continuous spacing function that would hang up the CPU.

Three failures of the 2501 card reader were caused by two lamp failures and a pinched wire. Both lamps, read station and TE (pre-read station), were the original components and over 10 years old. They are both on at all times. The pinched wire was aggravated into causing problems after the wire harness to the TE cell and the lamp assembly was disturbed to replace the lamp.

2. PDP-7 System

Maintenance of the LDC's PDP-7 computer system includes the peripheral equipment as well as the basic CPU. These devices include (1) a Burroughs Card Reader, (2) a KSR-35 Teletypewriter, (3) four MAI SC 7296 Magnetic Tape Drives, (4) a Versatec LP-1150 Line Printer, (5) a Data Control Unit, (6) a Serial Output Unit, and (7) a Paper Tape Reader-Punch.

There were 38 repairs on this system and 147 preventive maintenance actions completed. The repair distribution was:17 tape units, 7 teletypewriter, 4 line printer, 4 paper tape reader, 3 CPU, 2 card reader, and 1 Data Control Unit.

Twelve of the tape unit repairs were bulb replacements, adjustments, or sensor cleaning. All tape motion in the 7296 type units is controlled by photo cell assemblies. Two of the units had the rubber reel hubs replaced to prevent tape reels from slipping on the hubs. A capstan was replaced because of worn rubber coating and the bearings were replaced in a cooling fan. The head cam assembly cracked on one unit and had to be repaired.

The teletypewriter problems occurred on two different units, a KSR-35 and an ASR-33. The ASR-33 is a standby unit that was overhauled with the motor and drive gears replaced and print head and platen aligned. The on-line KSR-35 had several failures including a driver card, the selector clutch, and nylon drive gears.

The line printer had one serious failure when the diaphram ruptured in the toner pump, spraying toner all over the interior. After cleaning the unit and pump replacement the printer

operated properly.

The paper tape reader became unreliable because of a weak photo transistor (LS431) in the read head. A good LS431 was salvaged from a used head and the unit aligned.

Two 4215 cards failed in the CPU tape controller on two different occasions. The card in location C10 was dropping bit 8 in data from the tapes and the bad card in location C11 prevented loading any program from the tape units.

The card reader was occasionally dropping bits while reading cards without any apparent failures. A complete mechanical and electronic alignment was performed after which the unit functioned properly and reliable data was obtained. Mechanical wear had allowed all the adjustments to become marginal.

One problem in the Data Control Unit cabinet (PDP-7 Interface) prevented running the system program with LASA data. A terminal on the 15 volt distribution bus for the cabinet had come loose and arced causing an intermittant connection. When the connection was open the system program would halt and would not restart.

The ASR-35 teletypewriter received from ALPA was rewired to allow use with the PDP-7. We now have the ASR-35, a KSR-35, and an ASR-33 that can be used with the PDP-7.

3. Other LDC Systems

The other systems maintained at the LDC are the Digital, Analog, and Test and Support Systems.

The Digital System includes the PLINS, MINS, two identical timing cabinets, and the inverter operated power system. There were no repairs and 35 preventive maintenance actions performed on this system during this period.

The Master Clock Oscillator (MCO) in both the prime and standby timing systems were readjusted. The Time-of-Day clocks (TOD) had been drifting about 30-40 milliseconds per month. The MCO output controls the stepping of the TOD and all system timing signals. After the adjustments were completed the TOD had not drifted over a peak-to-peak range of 4 milliseconds in a 3 month period.

The Analog System covers the 96-channel D/A conversion equipment, the D/A patch panel, the analog timing equipment, the WWV receiver, and Develocorders. Completed were 14 preventive maintenance actions and 16 troubles corrected.

All of the corrected troubles were on Develocorders. All of the problems can be considered routine; galvo adjustment or

replacement, lamps, rollers, leaks, etc., except one failure to expose time and date on the film. To correct this, the Date-Time-Group assembly had to be dismantled and worn micro-switches S805 and S809 replaced.

One unit was overhauled by completely dismantling down to the frame, cleaning, painting, and replacement of all worn parts. Salvaged parts were used where possible.

The Develocorder rack was washed down and all rusted and corroded area rustproofed and painted. The general condition of the rack is good in spite of the chemicals used.

The LP Develocorder received from ALPA cannot be used in the LDC system. The scope system requires a multiplexed input not available at present. A project to design and construct a multiplexer will be considered in the future.

The one-half wave 5MHZ vertical helix-wound antenna for WWV reception has been fabricated. It will be installed this coming summer when weather permits. The need for this antenna was discussed in the last report and should improve the reliability of WWV reception on 5MHZ.

The Test and Support System encompasses not only the two Maintenance Display Consoles (MDC) but all other equipment for the support of the data center's operation such as the environmental equipment (air conditioners, electrostatic air filters) and the film viewers and copiers. Of 59 maintenance actions on this system, 32 were corrective and 27 were for preventive maintenance. Of the 32 corrective repairs, 23 were routinely expected bias battery replacements in the MDC units. The only other troubles that were of interest was the replacement of a battery in one of the emergency light units and repair of the humidifier system.

Inspection of the humidifier system found leaks from the ducting where it goes into the air conditioning system main duct. The ducts were completely rusted through in several places including the adaptor into the humidifier steam chamber. The system has been in use over 10 years. The adaptor and all ducting has been replaced.

All of the LDC environmental systems were cleaned and checked in March and all are in good condition and working properly. This includes the 15 ton roof-top air conditioner system, the humidifier, and the electrostatic filters.

C. Maintenance Center

The LMC supports the LASA operation with both array activities and shop testing and repairs.

The systems maintained by LMC are the SP, LP, SEM,

Power, and Weather Station.

The personnel at LMC completed 199 work orders representing 208 separate maintenance actions plus 17 items repaired in the shop. The array work orders included 50 corrective maintenance, 131 preventive maintenance, and one modification.

1. Array Activities

Table XV shows the array maintenance actions by system and month required to support the LASA during this 6-month period. To accomplish this maintenance, 107 visits to CTH's and 31 visits to WHV's were made during the period. This was done with 110 trips to the field plus 3 trips to the Malmstrom AFB, PMEL covering a total of 12,511 miles.

The 50 repairs made in the array consisted of 32 on the SP sensor channels, 10 for the power system inverter, 5 of LP amplifier, 1 LP free period motor, 1 SEM Control Drawer, and 1 SEM Input Drawer.

The SP repairs included 23 amplifier replacements due to failure or out of tolerance condition, 3 adjustments, 3 minor repairs, and 3 cut cables. The amplifier problems were not unusual or excessive. Two of the cut cable incidents were caused by Mid-Rivers Telephone Company contractors cutting across the buried cable to install underground telephone cable. Locations were leg 3 of subarray B1 and and leg 6 of subarray AO. Leg 4 cable of subarray C3 was cut by the landowner using a road grader on a trail. The barrel was badly damaged on WHV 23 at B4 by a plow. This WHV is not used so the barrel will be removed, the casing plugged, and the cable spliced when weather permits. One bit of excitement occurred when a LASA technician discovered a family of skunks had taken up residence under the cover of WHV 72 at subarray D4. Fortunately he was able to evict the tennants without incident. Bullethole damage was found at WHV 62 at subarray D2. The WHV had been shot up at close range with a large bore rifle. The cover, lid, and junction box was replaced and some cabling spliced and repaired.

The RA-5 amplifier, #394, at WHV 41 at D4 failed because of a bad battery, B3, in the feedback bridge. What was unusual about this amplifier was its longevity in operation from 2-18-66 till 12-6-76 without failure. Barring other component failures the usual average amplifier life before battery failure is 5 years.

The TD-202 short period tri-axial seismometer at subarray D2 was tested and adjusted to determine the system parameters:

		Natural Frequency	Damping Ratio (adjusted)
1.	Vertical	0.93 Hz.	15:1
2.	North-South	1.02 Hz.	15:1
3.	East-West	1.06 Hz.	15:1

The frequency response was measured and plotted and the curves matched the HS-10-1A on frequencies below about 1.15 Hz. On frequencies above this point the response is about twice as much on the TD-202. This would explain the increased sensitivity noted for this instrument to the higher frequency local seismic noise from machinery, vehicles, etc.

All of the subarrays were visited and checked during this six month period; the Snowcat was used several times. Subarrays B3 and C3 were not checked during January because of the weather and road conditions. There has been no evidence of damage at the subarrays from the winter weather and spring melt and run-off. All facilities will be inspected during April and May for physical damage.

There were 10 failures related to the Inverter in the Stand-by Power System. Most of the problems are the Inverter power breaker kicking off when ac power is restored after a failure. Several possibilities are being investigated and a modification will be developed to cure the problem if possible.

2. Shop Activities

The extent of the shop work is summarized in Table XVI. Shop activity is minimal during fair weather when most activity is centered in the field. When travel conditions limit field work, maintenance activity is concentrated on the shop repairs.

The large backlog of shop work (Type B and C work orders) is mostly RA-5 amplifiers, HS-10-1A seismometers, and printed circuit cards at LDC. Final adjustments of the amplifiers and seismometers are made with the units in the environmental chamber at operating temperatures. The first stage of the cascade cooling units failed in the chamber due to a bad compressor. The unit is now waiting parts for repair. When the chamber is back in operation, the repaired RA-5's and HS-10-1A's will be adjusted and the work orders closed out.

D. Facilities Support

LASA operations are supported by the facilities and vehicles available. These both require attention for their continued provision and maintenance. The land required for the array's CTH, LPV, and WHV structures as well as the buildings housing the LDC and LMC are essential. Insuring proper operating

TABLE XV

ARRAY MAINTENANCE ACTIONS

OCTOBER 1976 - MARCH 1977

	OCT	NOV	DEC	JAN	FEB	MAR	TOTALS
SP							
CORRECTIVE	6	8	6	9	3	1	33
PREVENTIVE	21	18	13	13	13	13	91
LP							
CORRECTIVE	0	2	3	1	0	0	6
PREVENTIVE	0	0	0	0	0	0	0
SEM							
CORRECTIVE	1	0	0	0	1	0	2
PREVENTIVE	8	6	6	4	3	6	33
POWER							
CORRECTIVE	0	1	2	1	3	3	10
PREVENTIVE	8	6	6	4	3	6	33
WEATHER STATION							
CORRECTIVE	0	0	0	0	0	0	0
PREVENTIVE	0	0	0	0	0	0	0
TOTALS	44	41	36	32	26	29	208

TABLE XVI

EQUIPMENT SHOP REPAIR SUMMARY

OCTOBER 1976 - MARCH 1977

	OCT	NOV	DEC	JAN	FEB	MAR	TOTALS
SEM ASSEMBLIES	0	0	0	0	0	0	0
SP ASSEMBLIES	0	0	2	1	0	0	3
LP ASSEMBLIES	0	0	1	0	0	0	1
POWER ASSEMBLIES	0	0	0	0	0	4	4
OTHER ASSEMBLIES	0	0	3	1	1	0	5
CARD REPAIRS	0	0	2	0	3	4	9
TOTALS	0	0	8	2	4	8	22

vehicles used for travel between facilities requires maintenance support.

1. Land Provision

Provision of the land for the array requires 50 leases. In the interest of good relations with the landowners, 72 contacts were made to deliver lease checks, discuss subarray access trails, and other matters concerning the land use.

There was not any drilling activity within the array that could affect seismic data during this 6-month period.

2. Land and Facilities Maintenance

The amount and type of utility work orders engaged in during this period for the LMC is shown in Table XVII. The 19 completed work orders show 4 for land repairs, 10 for facility repair/inspections, and 5 for vehicle maintenance/inspections.

The LMC facility was inspected by the local fire department on 2-3-77 and found satisfactory.

During the weekend of 2-19-77 several shots were fired from the southwest into the garage area of the LMC building. One round went through the window and into the door of one vehicle. but very little damage was done. The incident was reported and investigated by local police without success.

A contractor safely installed a water line across the cable trench located between WHV's 62 and 82 at subarray D2 on 1-21-77.

As mentioned in paragraph V.C.1. there were three instances of damaged cables in the array. The cable was cut by Sumners Construction Company laying underground telephone lines for Mid-Rivers Telephone Company near WHV 24 at subarray B1. It was dug out, repaired and covered by LMC personnel. The contractor did not cross the cable trench where it was flagged. The same contractor cut the cable near WHV 56 at subarray AO. LMC personnel repaired the cable and again the trench had been flagged. The cable was cut near WHV 84 at subarray C3 by the landowner blading trails. The cable was checked with the "cable-finder" and found to be very shallow in that area. Nearly 200 feet of cable was spliced in by LMC personnel to correct this situation.

3. Vehicles

Ford Aerospace & Communications Corporation provides three pick-up trucks for use at the LMC by the field crews and land agent and a Station Wagon for administrative/field inspections at the LDC. The trucks (two 1974, F113 models and one 1970 F110) are equipped with four-wheel drive and are specially prepared for travel over rough trails and use at the array sites. Minor vehicle

TABLE XVII

SUMMARY - UTILITY WORK ORDERS

OCTOBER 1976 - MARCH 1977

WORK ORDER TYPE	BACKLOG START OF PERIOD	INITIATED	COMPLETED	BACKLOG END OF PERIOD
CABLE TRENCH AND TRAIL INSPECTION	0	14	1	13
CABLE TRENCH BACKFILL	0	1	1	0
WHV SITES LANDSCAPED	0	1	1	0
MARKER POST OR WHV COVERS REPLACED	0	5	1	4
CTH MAINTNEANCE	1	4	5	0
VEHICLE MAINTENANCE INSPECTION	0	5	5	0
FENCE INSPECTION	0	0	0	0
TRAIL REPAIRS	0	0	0	0
LMC FACILITY MAINTENANCE	0	5	5	0
TOTALS	1	35	19	17

service and inspection is provided by the LMC for the trucks.

The government provides a fork-lift and a snow tractor. The LMC personnel serviced these vehicles (lubrication and oil changes) and no further maintenance was required for this period.

The mileage driven during this period in support of the LASA totalled 14,941 miles without any accidents.

SECTION VI

ASSISTANCE PROVIDED TO OTHER AGENCIES

A. Seismic Data Analysis Center (SDAC)

The LASAPS processor is operated at the LDC 24 hr/day and 7 days/week to provide real time array data on line to SDAC. The weekly near-regional reports with events and blasts within 20° of the array center are also distributed to SDAC.

B. National Earthquake Information Service (NEIS)

The LDC provides NEIS with the weekly reports of near-regional events and blasts, responds to their telephone requests for selected event information, and operates an FM telemetry link for transmitting data from three selected SP seismometer channels.

C. MIT Lincoln Laboratory

The periodic near-regional reports with the strip-mine blast supplements are distributed to Lincoln Laboratory.

D. Montana Department of State Lands

The strip-mine blast supplement to the near-regional reports is mailed to the Dept. of State Lands in Helena, Montana.

SECTION VII

DOCUMENTATION DEVELOPED

A. Technical Reports

The following reports were prepared and distributed during the first six months of this project:

1. "Montana LASA Operation Report for October 1976" T/R 2140-76-86, 8 NOV 1976.

2. "Montana LASA Operation Report for November 1976" T/R 2140-76-87, 7 DEC 1976.

3. "Montana LASA Operation Report for December 1976" T/R 2140-77-88, 7 JAN 1977.

4. "Montana LASA Operation Report for January 1977" T/R 2140-77-89, 7 FEB 1977.

5. "Montana LASA Operation Report for February 1977" T/R 2140-77-90, 14 MAR 1977.

6. "Montana LASA Operation Report for March 1977" T/R 2140-77-91, 7 APR 1977.

CONCLUSIONS

1. The LASAPS operation over the 4800-baud line was affected mainly by 360 computer failures and corrective maintenance this reporting period.

2. The LASA Inner Array Recording System operated satisfactorily to provide digital recording of the array data and to allow other array functions to be handled by the PDP-7 computer without interferring with the recording operation.

3. No decline in the overall performance of the Montana array systems has been observed. Increased 360 computer hardware failures are not presently considered as an indication of advanced aging.

4. Cultural noise surrounding some array sensor locations increased due to changes in local agricultural activity.

5. Daily teleseismic event processing at the LDC continues to be an important part of our array operation.

RECOMMENDATIONS

Based on the operation of the Montana array and data center during this reporting period, we recommend the following:

1. That the local study of daily teleseismic event reports be continued and that the Montana site be considered as a source of seismic event information not available at SDAC from the 4800 baud line.

2. That the telephone attached to the 4800 baud data set for SDAC/LDC operator communications be equipped with greater ringing power.

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REFERENCES

1. Potter, G. A. "LASA Inner Array Recording System (LIARS)" LASA Program Description. Ford Aerospace & Communications. Billings, MT. 26 MAR 75.

2. Matkins, R. E. "Montana LASA Semi-annual Technical Report" T/R 2126-76-75 (AD-A023263) Ford Aerospace & Communications. Billings, MT. 23 JAN 76

3. Needham, R. and A. Steele. "Montana LASA Data Analysis Techniques" S-110-33. Ford Aerospace & Communications. Billings, MT. MAY 69.

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

LASA - Large Aperture Seismic Array
Seismic Array
Seismic Observatory Operation
Seismic Measurement Channel Performance

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The continued operation, maintenance, and array improvement activities at the Montana LASA during the period between October 1, 1976, and March 31, 1977, are described. Array operations are detailed. Progress in seismic event processing is reported. Seismograph measurements, IBM 360 computer reliability and maintainability statistics, and PDP-7 computer programs are presented. Maintenance activities at the data and maintenance centers are discussed.

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